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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Development and Relative Value of the Emulsion and Demulsibility Tests

The Adjustment and Alignment of Bearings
Relation to Lubrication

PUBLISHED BY
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TEXACO PETROLEUM PRODUCTS

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A perusal of the two articles on the following pages will bear out this point. The first is a theoretical discussion of the accepted means of studying steam turbine oils for demulsibility and emulsion; and the second, a practical study discussing bearing adjustment and alignment.

We believe these articles indicate that when a Texaco Lubrication Engineer tells you to use a certain lubricant he KNOWS that it will work—right. That, as a matter of fact, is the reason why more and more engineers and operators in charge of lubrication in power plants, central stations, shops, mills, mines, ships and railways are specifying Texaco Lubricants and Texaco Lubrication Service.

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Development And Relative Value of the Emulsion And Demulsibility Tests

IN THE determination of the potential lubricating ability of a steam turbine oil, the tendency to emulsify is of decided importance. To assume the steam emulsion or the demulsibility number as an absolute criterion of the degree of success to be expected from an oil is erroneous. The respective tests must be properly understood and the true significance of their results appreciated, for the tendency of an oil to emulsify, as well as its demulsibility or ability to separate from water, is contingent upon a number of factors, such as viscosity, extent of filtration, the nature of the crude, and the manner of refinement.

The development of the several tests for determination of these characteristics forms an interesting chapter in the history of petroleum research. The Navy emulsion test and the test for demulsibility have been standard tests in the selection of steam turbine oils for many years. The Navy test, however, took precedence in its adaptability to the problem at hand, and the accuracy of its results; its purpose, of course, was to afford a knowledge of the rapidity with which an emulsion of oil and water would separate completely into its respective constituents. This thought is still the basis of the test today, as well as the more recently developed steam emulsion test. In fact, the essential difference between these two adopted methods is in the manner of bringing about the original emulsion.

Prior to the adoption of the steam emulsion test, however, Herschel developed his test for demulsibility at the Bureau of Standards. In contrast with the accepted Navy test, he chose to observe the rate of separation on a volume basis of a mechanically formed emulsion into its respective oil and water constituents, rather than the time of complete separation. According to Herschel*, the demulsibility of an oil denotes "the maximum rate of settling out of an oil from an emulsion in cubic centimeters per hour," when the emulsion is developed and the rate of settling observed as specified in Technical Paper 323-B of the Department of Commerce.

In consequence, this test is indicative of the tendency which a turbine oil will have to separate from water and oxidized matter in actual service. In effect, its purpose is to show that *"What is required is an oil which will de-emulsify between the time it passes through the bearing and the time it reaches the filter on its next journey around the circuit."

The steam emulsion test as adopted by the American Society for Testing Materials involves passing live steam into a measured quantity (twenty milliliters) of oil, under controlled temperature conditions of from 190 to 195° F. for a specified length of time, i.e., 4 to 6.5 minutes. The oil container is then transferred to a separating bath where the

*—Technological Paper No. 86, Bureau of Standards, by W. H. Herschel, P. 7-9.

surrounding temperature conditions can be kept within a range of from 200 to 203° F. The volume of the separated oil layer from condensed steam is observed periodically at not less than 30 second intervals, until 20 milliliters have separated. The elapsed time in seconds from withdrawal of the steam delivery tube until the above amount of separation has occurred is taken as the steam emulsion (S.E.) number.

According to the Society* in discussion of the significance of the results of this test:

"For forced-feed circulating lubrication systems where the oil is likely to come in contact with water or steam, the steam emulsion test is of great importance. This is particularly true of steam-turbine lubricating systems. For oils intended for this type of service the use of a test of this kind is thoroughly established. Next to viscosity it is considered the most important test for steam turbine oils, since rapid separation from water is an essential characteristic."

FACTORS EFFECTING DURABILITY

Research in the field of lubricating engineering has definitely proved that petroleum oils do not wear out mechanically, although they may become subject to more or less breakdown, dependent upon oxidation, the manner of refinement, and the intensity of the service to which they may be subjected. The development of emulsions and sludge will be the result of the above. It has been proved perfectly feasible to remove such matter from well refined oils, by adequate filtering or centrifugal treatment, to bring them back to a state of lubricating ability equal to that of new oil.

Oxidation

Of the several factors which may influence the durability of a steam turbine oil, oxidation is today regarded as probably requiring the most consideration.

Mineral oils will be subjected to more or less oxidation when agitated with water under higher temperatures in the presence of air.

These conditions are normally so involved and so contingent upon one another that no one of them can be rightly claimed as being more detrimental than the other. On the whole, however, it may be stated that the extent to which oxidation will occur depends largely upon the refinement of the original oil. In other words, certain petroleum hydrocarbons will probably oxidize more readily than others.

Logically, therefore, it would be advisable to bend every effort in the refinery to effect the removal of these components by careful and accurate refining. The more reliable the manufacturer, naturally the more dependence can be placed on his methods of refining.

Oxidation will, of course, occur in practically any oil if it is subjected to oxidizing conditions. In fact, wherever particles of air and water are suspended or retained within the body of an oil to form an emulsion, only a slight elevation of temperature during circulating or agitation will be necessary to bring about an oxidizing reaction between the air and oil.

Metallic Particles a Factor

Oxidation, furthermore, is aided by metallic particles, especially brass, copper, and iron, or other foreign matter, such as dust and dirt. In fact, in an already emulsified oil foreign matter of this nature is regarded as being the co-partner of oxidation in producing the resultant insoluble sludges so detrimental to proper lubrication.

It is believed by some that if emulsion is prevented, sludging will be greatly lessened. But emulsion involves only oil and water. It would, therefore, seem logical to consider foreign matter, or the catalyzers such as metallic particles which promote oxidation, as an equal detriment.

Emulsions alone are certainly not so viscous, adhesive, and generally objectionable as insoluble sludges which so frequently clog oil passages, congest the oiling system, and generally reduce the lubricating quality of the oil.

The natural procedure is, therefore, to reduce the effect by removing the cause as far as possible; in other words, by purifying the oil during operation to a sufficient degree to keep down the percentage of water, emulsion, and foreign matter.

The latter can also be prevented to a considerable extent by using steel piping and fittings throughout the oiling system, for steel has the least tendency to chip, corrode, or otherwise contaminate the oil with metallic particles as it passes through the lubricating system.

Sludge Formation—The Result of Oxidation

Sludge will result from subjecting a turbine oil to agitation in the presence of air or water, especially where overheating has occurred. There are two stages in this formation, viz.:

The colloidal or soluble stage, which is more or less of a primary development, and

The insoluble stage, wherein the sludge becomes permanent in form.

*—Significance of Tests of Petroleum Products, A.S.T.M., P. 38.

In the colloidal stage if water is present, fairly stable emulsions may be formed. On the other hand, the presence of an emulsion is not necessarily indicative of colloids. Both emulsions and colloidal sludges are relatively temporary at normal operating temperatures.

Emulsions, if uncontaminated and unoxidized, will clarify themselves and precipitate water on standing, leaving the bulk of the oil in very nearly the same condition as prior to agitation.

Colloidal sludges (or, as they may also be termed, soluble sludges), in turn, at temperatures above approximately 100° F., will be more readily held in suspension in oil. Yet, while both emulsions and colloidal sludges can be apparently readily dissipated from, or absorbed by, the oil they are nevertheless a detriment to lubrication while present, due to the fact that the formation of a continuous, uniform oil film over the surface to be lubricated may be impaired if coagulation occurs.

Where breakdown in an oil has occurred, it will interfere with the separation of contaminating foreign matter. As a consequence, this latter will exercise its catalyzing effect on further oxidation in the bringing about of permanent sludges.

Of course, where colloidal sludges have passed over to the state of insolubility, immediate steps should be taken to correct this by the removal of the heavy, adhesive, and relatively solid matter from the system, otherwise lubrication will be bound to be impaired.

Certain authorities are of the opinion, however, that oxygen may be a necessary factor in maintaining the internal friction within the lubricant as low as possible. On this theory, in all probability it would be the reaction of sludge formation and not the product itself which would require most consideration.

On the other hand, even though oxygen may ultimately be found to be essential to the attainment of satisfactory lubrication, the resultant product, i.e., the sludge, is a detriment just as has been stated before.

As a result, this sludge should be removed, due to its natural tendency when in an insoluble state to accumulate in the oil pipes and oil ducts, and not only impair the circulation of the oil, but also bring about an increase in internal friction. In its formation, sludge is directly influenced by the temperature of operation. Therefore, this latter should be kept down as much as possible. Where the oiling system is free from congested matter, the oil itself will be able to carry out its partial function of serving as a bearing coolant most effectively.

The Effect of Water

The detrimental effects of water have already been mentioned in discussing oxidation, emulsification, and sludge formation. If a turbine and oiling system could be so designed as to eliminate the chances of water leakage or condensation occurring, provided the original oil was water-free, there would very probably be but little emulsion developed.

It must be assumed, however, that the presence of a certain amount of water and other impurities is a certainty. As a result, emulsions and sludges will be formed in the average turbine oiling system. Effective oil purification should bring about the removal of these before their proportion becomes dangerous. From a constructional viewpoint, therefore, a turbine oiling system should be so designed as to permit of ready separation of impurities from the oil by means of the reconditioning apparatus.

How Water Gains Entry

The entry of water may occur through steam leaks on account of improper functioning of the shaft packing glands or water seals; through leaks in the cooling coils of the oil cooler; or, as is more usually the case, from condensation of moisture in the air. This latter is especially liable to occur when the turbine is shut down, at which time the inner metallic surfaces of the lubricating system will be relatively cold, serving to promote condensation more readily.

Water is considered detrimental to a turbine oil in service in that it is an active agent in the formation of emulsion and, under some conditions, sludge. Where the oil is in a sufficient state of purity, separation from water will normally occur comparatively readily, for the emulsion caused by agitation will be of relatively temporary character. A mixture of water and oil, however, when subjected to the customary rapid rate of circulation in the presence of air and the higher temperatures usually prevalent in turbine service, will oftentimes subsequently develop permanent emulsions.

Importance of Acidity

The relation which acidity bears to emulsification and sludge formation has been the basis of considerable study on account of the extreme complexity of the acid-forming constituents such as sulfur and oxygen, and the limited knowledge of their reactional tendencies. Were these reactions known more positively, or could turbine oils be so refined as to remove or more effectively neutralize their organic acid-forming constituents, certainly the matter of water and the possibility of for-

mation of permanent emulsions and sludges would cause far less concern.

As it is, effort can only be made in refinement to render turbine oils as chemically stable as possible. The most careful attention to the oil throughout the process of refining should always be observed. But no process renders an oil non-reactive when it is subjected to detrimental conditions in the presence of air and water under high temperatures.

General operating conditions are not conducive to satisfactory lubrication unless the turbine oil is capable of meeting requirements. In the first place, heat and air and water will always be present, since it is practically impossible to build a turbine oiling system so that the parts involved are absolutely airtight. As a result, air will get into the oil during its circulation through the system, or in splashing over the gears.

Dust and dirt are in turn always present in the air to a certain extent, wherever the oil is in passage. Therefore, it is logical to expect that foreign matter of this nature will find its way into the oil, not only to cause abrasion and corrosion, but also to act in the same catalytic manner as metallic particles.

Furthermore, the matter of acid and alkali must be taken into account. A turbine oil should always be neutral from this point of view. As previously discussed, organic acids may or may not be detrimental, depending upon the type of acid.

FOAMING

In a discussion of the reasons for emulsification and sludging of turbine oils, the relation of foaming to oxidation must be understood. In turbine parlance, foaming involves accumulation of air by the oil. It is indicated by formation of bubbles and more or less foam. Where an oil-level gauge glass is located in the oiling system foam will often become first noticeable at this point.

There are a number of causes of foam. It may result from

(a) The splash developed by rapid addition of an excess of new oil.

(b) The pump suction becoming exposed due to low oil level, or rolling of a ship in marine service.

(c) Faulty adjustment of the relief valve, to develop an abnormally high discharge pressure, especially when the return oil in a circulating system is delivered back to the system above the normal oil level.

(d) Churning of oil by the gear teeth in a reduction geared pressure oiled system. In such installations, the oil level should never be so high as to enable the gear teeth to dip therein, the oil spray from the circulating system being sufficient to maintain adequate lubrication.

(e) Splashing of oil by the oil rings in a ring-oiled bearing where the rings revolve at abnormally high speed, due to low oil level in the reservoir and speeding up of ring rotation on account of reduced oil resistance. As the rings rotate through the oil in this manner, splash and oil spray is developed inasmuch as the angle of entry of the rings is less, thus permitting the exterior surfaces of the latter to strike against the surface of the oil rather than to enter it cleanly. The tendency under such conditions is for the rings to draw air into the oil. In certain types of bearings this will lead to considerable loss of oil through leakage of spray or foam.

In view of the fact that oxidation is so intimately related to heat and sludge formation, it is well to consider that foaming in certain installations may lead to overheating of the oil and thereby promote oxidation. It may, in fact, be directly responsible for the ultimate developments of serious sludging. While distinctly a mechanical cause, the result might easily be interpreted as an indication that the original oil was unsuitable. For this reason, foaming should not be passed over with but casual consideration. Where it is evident, the cause should be promptly investigated. In reduction geared units, special attention should be given to the oil level and the extent to which the gears may be causing excessive churning and splash. Frequently reduction of temperature and discharge pressure will materially reduce the tendency of an oil to foam.

The viscosity of the oil must also be considered in this regard. The heavier or more viscous the oil, the less readily will it aerate or free itself from entrained air. In view of the fact that reduction geared turbines require higher viscosity oils than direct-connected units, except where abnormally high bearing temperatures may prevail due to proximity of the bearings to the turbine casing, one should remember that the oil in a geared machine will require more time for deaeration than a light oil for a direct-connected unit. In particular, this thought should be borne in mind when adding new or make-up oil to the system. Authorities have dictated that ten percent of new oil should be the maximum added at any one time. It is further recommended that

the temperature of the make-up oil be of as nearly as possible the same temperature as that of the oil already in the system. The oil should preferably be poured in through a long spout funnel to reduce the possibility of splashing as much as possible.

The Adjustment And Alignment of Bearings

Relation to Lubrication

IN THE operation of many types of machinery, the importance of certain details of maintenance are frequently overshadowed by the more apparent matter of production. Industrial plant equipment will often suffer markedly in this respect. But, after all, it is a natural attitude for the operator of such a plant to assume, for he is held chiefly responsible for production, rather than the economies of maintenance of his particular machinery.

Not so in the power plant, however. Here maintenance costs as well as the cost and amount of power produced are regarded as of equal importance by the engineers. Maintenance, in fact, is even more strongly stressed in marine practice.

In considering this subject of maintenance, machine alignment and bearing adjustment are of particular importance in the interests of safe, economical, and efficient operation. Primarily, this is due to the fact that wear cannot be entirely eliminated even with the most effective lubrication.

The various bearings of any machine should receive attention from time to time according to existing conditions. At the time of erection, all such bearings are put in alignment; if they all wore equally, this alignment would be preserved indefinitely. Unfortunately, however, they generally wear and settle irregularly.

The manner in which a bearing has been working both as to noise and temperature will usually indicate whether or not adjustment is necessary. The adjustments of bearings, consisting mainly of alignment, fitting, and grooving are comparatively simple, yet these adjustments must be carefully and correctly made or continual and serious trouble may result.

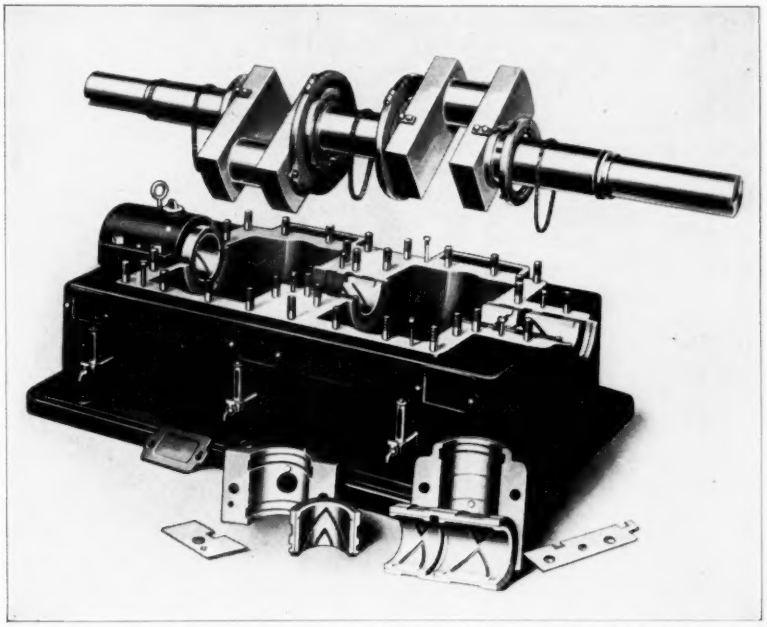
Causes of misalignment of a shaft may be traced to one or more of the following:

(1) A bearing may have run hot and the babbitt metal melted away or become displaced.

(2) The composition of the babbitt may not have been alike in all bearings.

(3) One bearing may not have been lubricated as well as the others.

(4) The load on the shaft may have been unequally distributed.



Courtesy of Anderson Engine and Foundry Company.

Fig. 1—Showing an engine base and crankshaft, with respective bearing elements. Note in particular the manner of grooving the bearings, and the chains, which insure circulation of oil to each respective bearing.

(5) The foundation of the machine may have settled unevenly, or the top of a foundation may have deteriorated by oil leakage below the bedplate.

ALIGNMENT

The state of alignment of many shafts and bearings can only be definitely ascertained by dismantling the machinery of which they form a part; in other cases, this alignment can be checked by bridge gauges, micrometer gauges, etc., and supplemented by the results of inspection. In this connection, it should be observed that cylinder liners and valve seats are bearings, in the same sense as those other fixed surfaces which support line shafting, crossheads, crankshafts, and other moving parts.

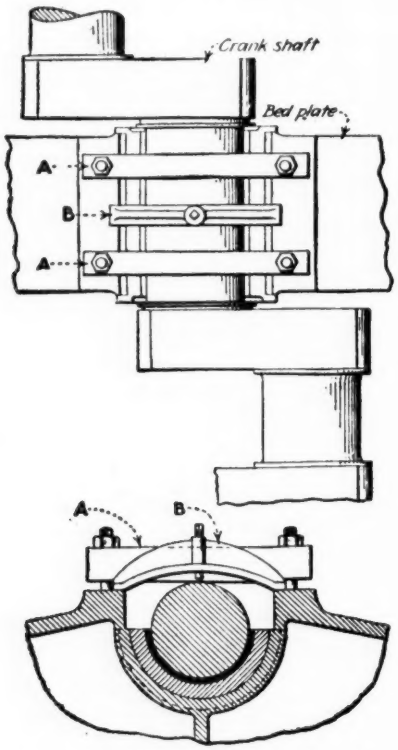


Fig. 2—One way of testing shaft alignment is to replace bearing by straps "A" as shown, laying a piece of wood or copper between strap and shaft and tightening the nuts, thus pressing the shaft tight on the lower bearing shell. A testing tool "B" is arranged in place and a feeler gauge used to measure the distance between shaft and set screw of the testing tool. After a shaft is once properly aligned, its exact alignment can be conveniently checked in this fashion.

It is unusual for any piece of machinery to develop misalignment without giving preliminary warning of this condition. On the other hand, the seriousness of lack of alignment depends on the type of machinery involved. For example, in a reciprocating engine, lack of alignment will usually be indicated by noise and by generation of heat long before any serious damage results. With a turbine installation, however, a marked departure from correct alignment cannot long exist without damage to material and failure of operation. Where machinery operates long shafting, a considerable lack of alignment will be absorbed by the flexibility of the shafting before any serious warning or whipping of the shafting occurs.

If the amount that a shaft has to be moved to correct misalignment is very slight, the position of the bearings involved can be altered in small installations by inserting liners and springing the piping, etc. Whenever it is believed that a shaft is out of alignment, it should be checked by slacking the coupling bolts at a coupling near which the error is suspected and inserting feelers between the coupling flanges. If there is a greater distance between the faces at one part of the coupling than at another, it shows that the shafts are not in line at the places where there is a tendency for the flanges to separate.

BEARING CLEARANCES

In order to allow for the circulation of oil and to permit the formation of an oil film between a shaft or journal and its respective bearing, the latter must be so fitted that it is slightly larger in diameter than the former. This difference in diameter allows a certain amount of play between the journal and the bearing. The space between the two is called the "bearing clearance."

This clearance must be uniform throughout the entire bearing, except that it is usual with large bearings to "crown the brass," i.e., to allow a slightly larger clearance at the sides. Crowning prevents the journal being nipped in case a bearing runs warm, and it also makes it easier to handle the brass on and off

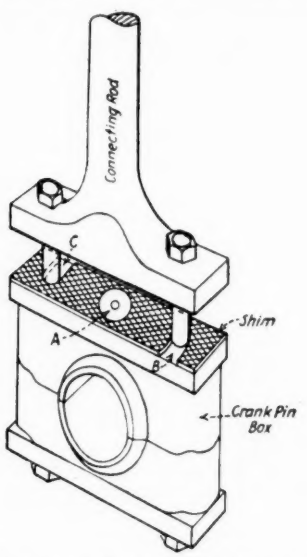


Fig. 3—Illustrating a method of cutting shims or liners whereby they can conveniently be inserted or removed between the stub end of a connecting rod and a crank box in order to obtain the proper clearance.

the journal during the process of fitting. If the clearance is not uniform throughout, only a part of the bearing surface takes the load, and the friction on this limited surface will tend to cause the bearing to run warm.

In assembling a bearing the abutting surfaces must be virtually set up metal to metal, leaving just sufficient space for an adequate film between the journal and the bearing metal. The objective is to reduce this clearance to a minimum, but at the same time, to insure sufficient play to prevent heating. The amount of clearance depends on:

(a) The size of the bearing.
(b) The general alignment.
(c) The speed of revolution.
(d) Whether the direction of the load force alternates, as in reciprocating units, or remains constant, as in rotating units.
(e) Whether gravity or pressure lubrication is used.

Small brasses are adjusted by feel, but with bearings of any size leads should be taken to determine accurately the amount and uniformity of clearance. The amount of clearance in a properly fitted bearing is regulated by the thickness of liners between the abutting surfaces. Copper, brass, or paper should be used for liners; tin rusts, and is therefore not desirable though its cheapness is the reason for its sometimes being employed. Liners should be held in place by dowels and should be made so as to be removable without drawing the bolts. The practical engineer usually has extra liners on hand of various thicknesses for all his important bearings.

Large bearings, such as main engine and crank-pin bearings, are often given clearances as high as fifteen thousandths of an inch, while small bearings may be set up to two or

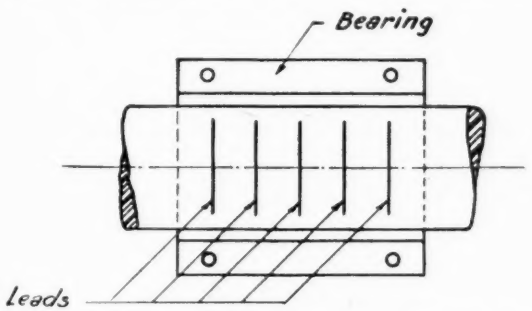
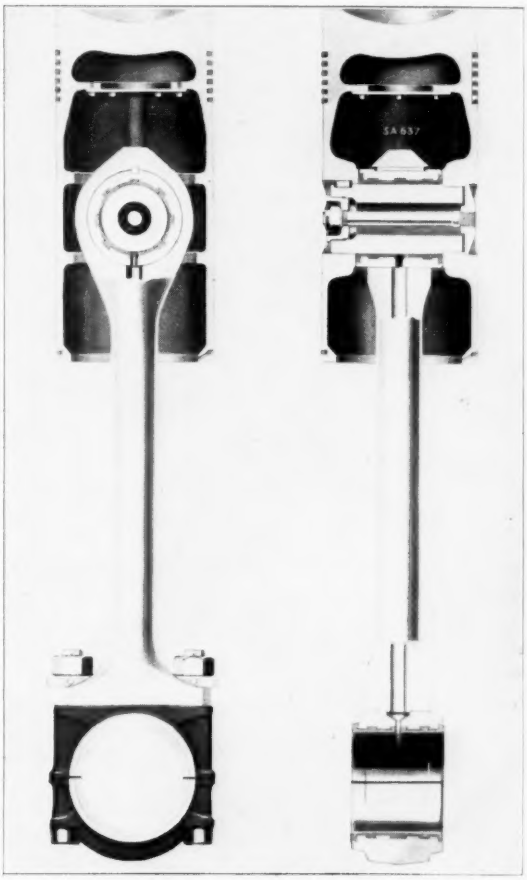


Fig. 4—Showing the manner in which leads should be located equidistantly on a journal prior to adjustment of the bearing cap.

three thousandths of an inch. As a general rule the bearings of reciprocating engines are given slightly greater clearance than are the bearings of similar size on machines where the direction of the load force remains constant. A carefully lined up set of bearings can be adjusted to closer clearances than can a set wherein the alignment is not so exact. Bearings of an installation fitted for pressure lubrication can be adjusted to finer clearances than



Courtesy of Worthington Pump and Machinery Corp

Fig. 5—Piston and connecting rod details for a Diesel engine. Note manner of construction of connecting rod and piston pin bearings. In this type of engine each bearing is pressure lubricated by oil distributed from the main circulating system.

those of an installation fitted with gravity lubrication.

TAKING LEADS

The method generally used in measuring the clearance of a bearing is called "taking a lead." This is done by removing the upper half of the bearing, laying several lengths of soft lead wire on the journal and replacing the bearing cap. All bearing nuts are then set up hard and the position of each one marked. The top half of the bearing is then removed again and the leads carefully taken off the journal for examination and calipering.

When leads are to be taken, care must be exercised that all bolts, bolt holes, bearing surfaces, liners, and butting faces are free from foreign matter. When assembling a bearing

and its liners preparatory to taking leads the bolts are inserted so that the dowels are in place. The nuts are run down hard to bring the bearing cap solidly against the liners, metal to metal. Precaution must be taken as any further application of force to the nuts results in straining the threads or the metal of the bolt.

To set up the nuts of large bearings in restricted spaces, short heavy wrenches are used and are driven around by sledges. The sound of the sledge striking the wrench when the nut is home, combined with the small movement of the nut, indicates to the experienced engineer when to stop setting up. The bearing nuts must be marked in this position and record of the position noted in order that the nuts may again be tightened the same amount after the leads have been removed. When the bearing nuts are finally set up, after taking a lead and adjusting the clearance, the locking devices are secured; a record of the clearance to which the bearing was adjusted should be made for future reference.

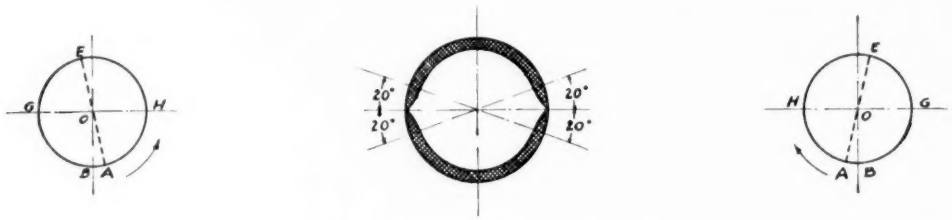


Fig. 6—Load diagrams for a typical bearing. Note discussion in the accompanying text.

When leads are removed from a journal, one end of each lead should be pinned to a piece of paper, the leads being the same distance apart and arranged in the same order as they were on the journal. Each lead should then be carefully examined. If the wire is spread out evenly along its entire length, the clearance is uniform. If it is squeezed out wide in some places and narrow in others, the clearance is irregular, being least at the wide spots and greatest at the narrow portions.

Each lead should be carefully measured with a micrometer at several places along the length of the wire in order that the amount of clearance at all points may be accurately known. If the lead is thick on one side of the journal and thin on the other, a liner will have to be inserted on the thin side or one will have to be removed from the thick side. If the clearance throughout is too small, liners will have to be inserted; if too large, liners will have to be removed. If the lead shows much unevenness of bearing surface, the bearing should be removed and the high spots ground or scraped down.

It is of prime importance that all journals be kept smooth, free from rust, and even at all times. To remove spots of rust, ridges, etc., the journal should be dressed with a fine file and then lapped with an oilstone or with oilstone powder. Carborundum is preferred by some engineers, but where it is used great care must be taken to remove all particles, as these will cause cutting and grinding of the bearings if allowed to remain.

The nature of the contact between the bearing and the journal is tested by lightly smearing the latter with red lead or prussian blue and then applying the brass in place and rotating it back and forth. The high spots will be shown by the color. They should be further dressed down until a satisfactory fit is obtained.

At times where bearings are thus fitted up, each one may show a satisfactory fit when tried separately and without external constrain, and yet when in place they may be unable to come to the same relative positions on the journal to make satisfactory contact with it. For this reason it is preferable to test the contact with the bearings together and regularly secured in place, providing the additional time required is available.

ADJUSTING BEARINGS BY FEEL

The amount of clearance with very small bearings is often judged by "feel." A bearing is ground in, scraped or fitted, and then assembled after first covering the journal with red lead, prussian blue, or a similar substance. The bearing nuts are then set up hard. If the clearance is correct there will be only the slightest indication of play between the bearing and journal, and the latter will revolve easily within the former. The bearing cap is then removed and if the greater part of the surface shows contact the bearing is satisfactory; if this condition does not exist, the high spots must be scraped in.

With heavier bearings, of the crosshead type, for example, the clearance can also be adjusted by "feel." In such cases the bearing is scraped and fitted, and just a sufficient number of liners inserted to insure that when the nuts are set up to their proper limit, the rod will slowly swing to a vertical position if the cross-

head pin is held stationary and the rod swung toward a horizontal position and then released.

In cases where time is limited, adjustment of the clearance of a large bearing may be effected without the taking of leads, by removing the liners and setting up on the nuts until the brasses bear full on the journal. The positions of the nuts are marked and they are then backed off a certain amount, determined by judgment or experience with the particular circumstances of the case; liners are then inserted to fit this adjustment. While this method is not as satisfactory as taking leads, it is much quicker and good results can be obtained by an experienced engineer.

OIL DELIVERY TO BEARINGS

After a bearing has been fitted to a journal, means must be provided to insure the proper distribution and circulation of oil, for both lubricating and cooling purposes. In bearings wherein the direction of the load force alternates, as in main bearings of reciprocating engines, the pressure is greatest on the down stroke, in the lower half of the bearing at "A" (See Fig. 6), a few degrees ahead of the load force "OB" decreasing to point "E" diametrically opposite. On the up stroke conditions are reversed, the greatest pressure being at "E" and minimum pressure at "A".

In turbine and similar bearings where one direction of rotation prevails the conditions are always as on the down stroke of a reciprocating engine. In gear and pinion bearings the resultant load force assumes various positions dependent upon the tooth angle, the number of teeth, etc. Oil should be delivered at a point where the pressure is slight, and, as a general rule, it is supplied to the bearings at a point in the vicinity of "G"; in forced lubrication systems the outlet is fitted at a point near "H".

In order that the flow of oil at the intake and outlet points may not be restricted, bearings should be bevelled at these points for an arc of about 20 degrees at the joints where the bearing halves come together (Fig. 6), except for a narrow strip at the ends, where full thickness of the metal must be retained to prevent the loss of oil through leakage.

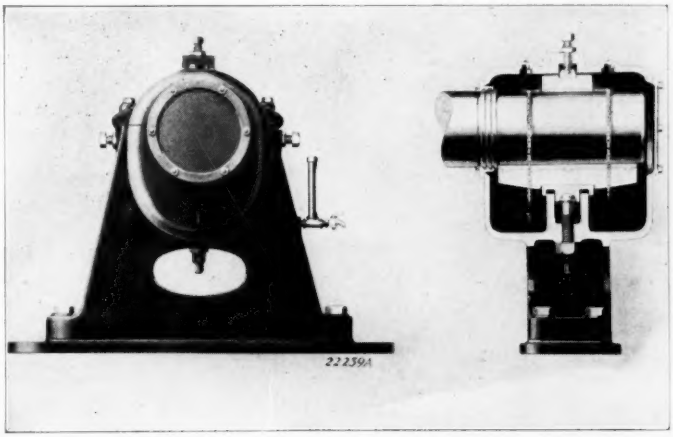
The function of a bearing oil is both to lubricate and cool the bearing. The oil which lubricates is that which forms the film between the shaft or journal and the bearing; the oil which does the greater part of the cooling is that which passes over the parts subjected to the least amount of pressure, absorbs the heat, and carries it back to the system.

The oil which lubricates is subject to great pressure and, as it may be supplied at but little pressure in certain types of oilers, the force which maintains the film must originate in the bearing itself. Experiments have proven that this force is generated by the pumping action of the journal revolving in the bearing.

OIL GROOVING

The cause of much trouble as well as large wastage of lubricants can be directly attributed to the improper grooving of bearings. An operating engineer will do well to consult with the manufacturer of his equipment regarding the simplest and most effective manner of grooving bearings, should occasion require their remetaling. Interference in any manner with the attainment of full pressures within the oil film will cause a bearing to run inefficiently, i.e., lower its carrying capacity. It is exactly for this reason that oil grooving in the high pressure zone would appear to be poor practice, as such grooves interfere with the development of the oil film in this zone, permitting the oil to escape too readily. Oil grooves in the low pressure zone, however, interfere very little, if at all, with the generation of the necessary pressures within the oil film. Furthermore, they facilitate introduction of the lubricant into the bearing.

In high-speed machine bearings, for example, the pumping action is such as to maintain a perfect oil film between the journal and the bearing surface. Oil grooves in either the upper or lower halves instead of aiding in maintaining the oil film tend towards its breakdown and for this reason are often not provided. However, some manufacturers of high speed installations do groove the upper half of a



Courtesy of Ingersoll-Rand Company.

Fig. 7—An outboard bearing for a Diesel engine, showing bearing construction, chain oilers and adjusting devices.

horizontal turbine bearing, but this grooving differs greatly from the oil grooves that were at one time cut in all bearings. Instead of being narrow and deep, they are wide and

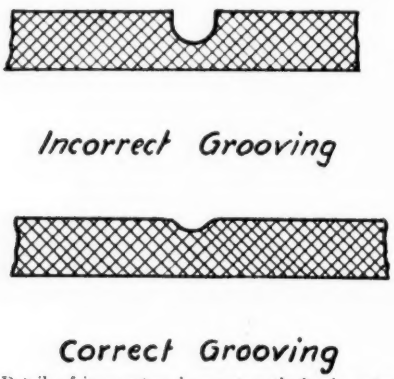


Fig. 8—Details of incorrect and correct methods of cutting grooves in bearing metal.

comparatively shallow. This method of grooving results in the formation of bearing strips in the upper half of the bearing. The clearance between these strips and the journal is much less than the clearance between the bottom of the grooves and the journal. When bearings are grooved in this fashion, the oil film is maintained, but is thicker at the grooves than at the strips, and bearings can be set up much closer than where no grooves are cut. The small clearance at the narrow strips insures a minimum of vibration and the wide, shallow grooves between the strips insure a plentiful supply of lubricating oil for cooling purposes.

It is a customary practice to fit both halves of turbine bearings to the journal through an arc of 130°, slightly bevelling the metal where the bearing halves come together in order to allow for free passage of oil. This bevelling of the bearings where the respective halves join, the oil clearance, and the pumping action of the shaft or journal insure circulation of a sufficient amount of oil to carry away the heat generated.

Bearing halves of reciprocating machines are also usually grooved. Here likewise the simplest form of grooving should be employed, and the clearance enlarged at the sides as in the case of turbine bearings. For a small bearing the Type 8 groove gives excellent satisfaction; for large bearings a main circumferential groove from which lead several axial grooves is recommended. In order to prevent oil leakage the axial grooves must not extend to the end of the bearing. The point which must be borne in mind is that where grooving is permitted, as little as possible shall be done, yet care taken to insure a sufficient supply of oil evenly distributed over the entire bearing surface.

Causes and Treatment of Hot Bearings

One of the most important of the many troubles which may arise in the operation of machinery of any nature, and one which may lead to serious consequences in case the proper steps for control are not taken promptly, are hot bearings. Some bearings, of course, operate satisfactorily at much higher temperatures than others. Therefore, it must be borne in mind that the point to guard against is not high running temperature of a bearing, but an increase above the usual temperature. A bearing which persistently runs warm when known to have been properly fitted and kept supplied with an adequate quantity and quality of lubricant, free from grit or other foreign matter is a rather definite indication of misalignment of machinery.

If the temperature of a bearing continues to rise after the oil supply has been increased, the condition known as a "hot bearing" develops. The danger of a hot bearing is that the bearing metal or brasses may expand until they grip the journal, thus causing a constant increase in friction and heat. When the temperature reaches the melting point of the metal the latter will run.

Indication of Trouble

The condition of bearings can be determined

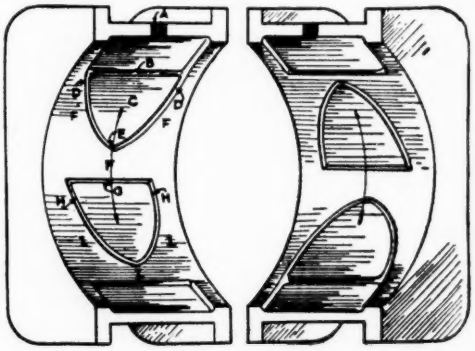


Fig. 9—Crank-pin boxes of a connecting rod showing oil grooves. Oil enters at "A"; is accumulated in the primary groove "B"; by rotation of the pin from there it is spread in both directions within the clearance space to cover surface "C." "D-D" are secondary grooves which carry oil back to the center of the bearing at "E" and at the same time maintain a film of oil over surfaces "F,F,F." From here oil works into primary groove "G" and thence to secondary grooves "H, H" where the course of development of the film is repeated as above.

to a large extent by sound and feel. In the ordinary course of machinery operation, there is a regular sequence to the various sounds, deviation from which is quickly noted by the

trained ear. One of the most alarming indications is the sudden cessation of noise which almost invariably accompanies the heating of a large bearing, it is soon followed by the smell of hot oil.

Pounding in a crank pin or main bearing causes a dull, heavy thump, which occurs just after the crank passes the center. A main bearing pound gives a duller and more severe knock than a crank pin and it can easily be located by feeling to see if the shaft jumps in the bearing. A crosshead knock is sharper and is not heard at much distance. If a knock is difficult to locate, the suspected bearings should be flooded with oil in succession. When the loose bearing is reached, the knock is deadened and is thus located. A sudden rise in the temperature of a bearing is a certain indication of trouble.

Methods of Treatment

The treatment of a heated bearing involves two chief objectives, viz., the removal of the cause and the restoration of the bearing to its normal condition. As a rule hot bearings may be traced to one or more of the following causes:

(1) Improper or insufficient lubrication.
(2) Grit or dirt in the oil.
(3) Bearings out of line or set up too tightly.
(4) Uneven surface of bearing or journal.

The cause of a hot bearing may, of course, be corrected, by stopping the machinery, and in an advanced case of trouble this may be necessary. Otherwise it may be reduced by slowing down somewhat, and thus decreasing the amount of work thrown on the bearing. It may be further decreased by easing up the bearing cap and thus increasing the clearance between journal and bearing surface, but this can only be done to a slight extent, otherwise trouble will follow from too great a clearance.

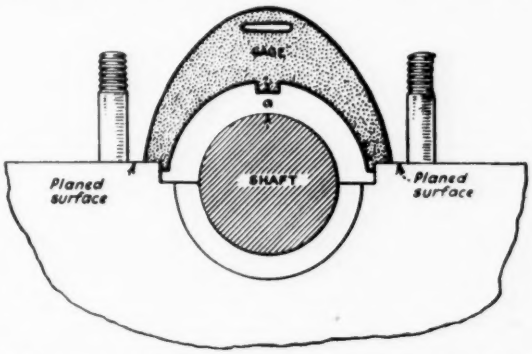


Fig. 11—It is a good practice to make a bridge gauge when a shaft is installed so that the original shaft line can be established in terms of bridge gauge clearances and these clearances permanently recorded by stamping on the gauge or on the engine bed. After a shaft is bedded in and accurately lined up the clearance at "a" between shaft and center lug on the sheet metal gauge is measured on each bearing. Any subsequent deviation from these readings will show how much the shaft is below or above its true central position.

If the trouble is due to insufficient lubrication and is discovered before the metal has wiped, an abundant supply of oil will be usually sufficient to control the condition and to gradually bring the bearing back to its normal temperature. Should investigation indicate that the oil is too thin (i.e., that the viscosity is too low) so that it will not remain in place in the bearing and sustain the load, the lubricant should be changed at the first opportunity.

If bearings are out of line, if they are set up too tightly or if they have been improperly fitted, the fault cannot be fully remedied until the improper adjustments are rectified. In such cases only temporary relief can be looked for from the various means suggested, the most effective of which will presumably be the operation of the machinery at a low or moderate speed until such time as the needed readjustments, changes, or repairs can be effected.

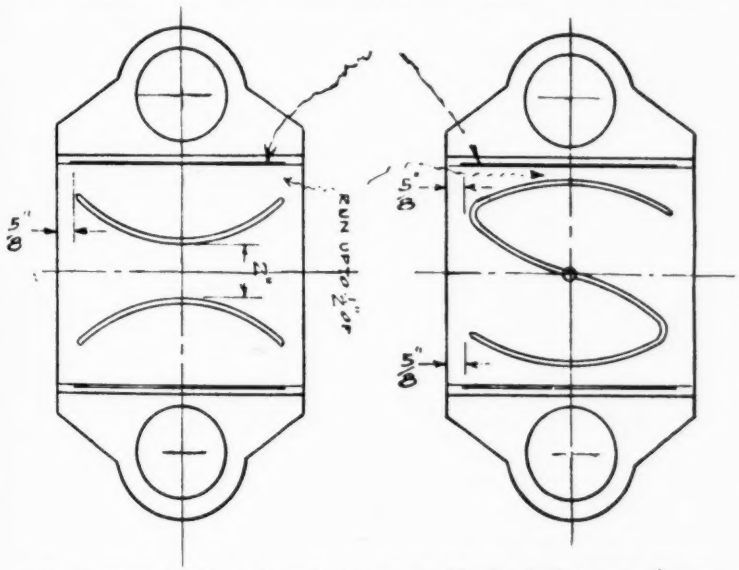
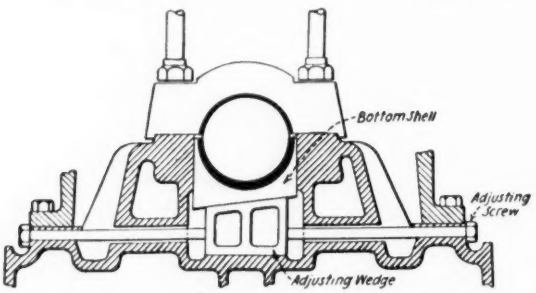


Fig. 10—Dimension details of a marine type crosshead bearing showing manner of grooving and chamfering of bearing edges. In this bearing grooves are approximately ¼" wide by 3/16" deep. Top half is shown at right, with the bottom bearing at left. In preparing such bearings all burrs must be removed and grooves eased off at the ends.

Where the cause may be due to an accumulation of dirt on the bearing, a copious supply of oil will generally flush out the impurities sufficiently to permit operation. Should it be determined that there is grit, dirt,

or other foreign matter in the oil the reason may be improper operation of filters or purifiers where these are installed for the cleaning of the lubricant. In such a case the oil supply should be thoroughly renovated or a fresh supply ob-



Courtesy of Ingersoll-Rand Company.

Fig. 12—Showing method of providing an adjustable bottom bearing shell where a form of wedge shaped block is employed under the bottom shell. This can be moved by a long screw extending through the bed plate to where it can be easily reached with a wrench.

tained; wherever possible the lubricating system should be examined and cleaned, depending on the extent of the trouble encountered.

Where large machinery bearings are fitted with pipes for water circulation to insure low bearing temperatures, a stoppage of the water flow for any reason may readily cause a rapid rise in temperature. In some cases where a hot bearing has developed it may be necessary to play a stream of water directly on the bearing although this is not recommended. Should it happen, as may readily be the case in certain types of service, that suspended sediment or sand is in the cooling water this may work into the bearing and cause more heat than can be subsequently removed. There is a serious objection to external use of water, however, in that where a bearing is very warm, the sudden application of cooling water may result in bending, warping, or cracking, due to the unequal contraction or alteration of the chemical structure of the steel.

TREATMENT OF HOT RODS

Overheating of a piston rod or valve rod may also have serious consequences. It may give rise to springing of a rod, or, if this latter is allowed to become very hot, the metallic packing may melt, causing a serious water leak in the case of steam machinery, or blow-by in Diesel engines, with the possibility of complete breakdown.

Usually a hot rod is due to one or a combination of the following causes:

(1) Insufficient lubrication.
(2) Presence of dirt or grit.
(3) Improperly fitted packing or
(4) A rod out of line or badly scored.

When a rod commences to heat, it is usually accompanied by a smell of burning oil. The measures to be taken in overcoming the trouble depend on conditions. If the rod is only slightly hot, free application of oil will usually reduce it to normal running temperature. Furthermore, the stuffing box gland can be slackened, heating caused by the friction of the packing can thereby be reduced. If the rod is very hot, however, the engine must be slowed down or stopped to reduce the load and prevent the rod from bending.

Water should never be applied to a hot rod, as the sudden cooling and contraction of one part will in all probability cause bending or distortion, especially if the rod is hollow. Whether or not a rod is running out of line can be fairly accurately determined by noting if it remains central in the stuffing box throughout the stroke, or by taking a line of sight tangent to a fixed part of the engine and the rod throughout its stroke.

If the cause of a rod heating is suspected to be due to grit or dirt, the introduction of a quantity of kerosene into a steam engine cylinder or valve chest will assist in removing foreign material which may have collected at or around the stuffing boxes or metallic packing. Steam rod and valve stem stuffing boxes are frequently a source of considerable loss of power if they are not kept in good condition or if the rod is in misalignment.

In general, the tightness of all varieties of metallic packing depends on the fit and cleanliness of the component parts and the condition of the rod. No external adjustment is possible, and the only remedy for a leaky stuffing box is to tear down, clean and refit or renew the worn parts. The underlying principle of all metallic packing is a tight fit of white metal rings held against the rod by a comparatively light spring pressure. If too much spring pressure is exerted, the resulting friction will cause a hot rod and may melt the packing.

If a piston rod or valve stem is badly out of line, the condition can probably only be corrected by a complete alignment of the machinery, which is an extensive job, as it requires that the engine be entirely stripped. Where it is found that a rod has only light scores and rough spots, these can usually be stoned to remove sharp edges without disturbing the machinery. A rod must be reground if badly scored or out of round, and when this is done new packing rings of appropriate dimensions will be required.

ERRATA

In the caption for Fig. 8 of the July-August issue of "LUBRICATION," error was made in the use of the name Cochrane in connection with a grease covered grid from a multiple baffle separator. The Cochrane separator has a single ribbed baffle.

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